Summary of the Argonne Measurements of the LBL
Prototype Pickup Characteristics

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During the past year we have conducted a series of tests on the LBL prototype 1-2 GHz and 2-4 GHz stochastic cooling electrodes at Argonne Chemistry Division's electron LINAC. The electrode geometries are illustrated in Figs. 1 and 2. Using the test electron beam, the 16-loop arrays were operated as beam current pickups and their sum (Σ) and difference (Δ) mode coupling impedances were measured.[1]

The LINAC operates at 20 MeV and has a variable pulse rate from 1 to 800 Hz. We operated at 800 Hz. A typical pulse has a width of 30 picoseconds and a total charge of 9 nanocoulombs. In order to maintain an acceptable beam size through 1.5 meter pickups, the linac beam was collimated to an emittance of

$$\varepsilon_{x,y} \approx 2.5 \ \pi \ \text{mm-mrad} \tag{1}$$

This corresponds to ~ 1% of the initial beam current.

We fast Fourier analyzed the time domain output response from the pickups. For example, for the 2-4 GHz system we chose the maximum frequency analyzed to be
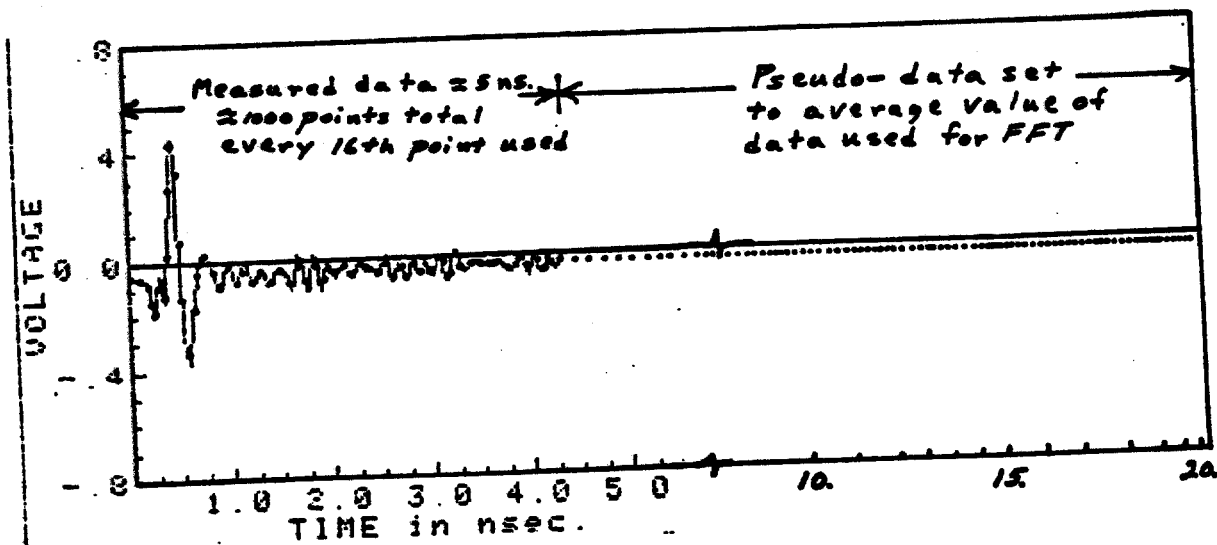
$$f_{max} = 6.25 \ \text{GHz} \tag{2}$$

corresponding to the 128th harmonic of a fundamental frequency interval of

$$f_o = \frac{f_{max}}{128} = 48.8 \ \text{MHz.} \tag{3}$$

This corresponds to a total time interval sample of

$$\tau \sim \frac{1}{f_o} \sim 20 \ \text{ns.} \tag{4}$$

divided into 256 data points. A typical time domain oscilloscope picture looked as follows:

The coupling impedance is

$$Z_c^\alpha (\omega) = \frac{V_{out}^\alpha (\omega)}{i_b (\omega)} \,.$$
(6)

Finally, we obtained Z_c^α by averaging $Z_c^\alpha (\omega)$ over 2-4 GHz. The 1-2 GHz system was measured and analyzed analogously, except that f_{max} was 5.0 GHz in the Fourier analysis and the averaging was for 1-2 GHz. Again the number of data points used was 256 and the number of harmonics was 128.

In Figs. 3-6 we graph the calculated sensitivities $s(x,o)$ and $d(o,y)$ for the 1-2 GHz and 2-4 GHz systems.[2] In Figs. 7-12 we graph the various calculated and measured coupling impedances. All of these values are shown in Tables I-VIII. The horizontal offsets for the data in Figs. 7, 8, and 12 are due to the small uncertainty ($\approx$ 1 mm) of beam center. For this report we have ignored the effect of the beam width, which has been analyzed and shown to have only a $1\frac{1}{2}$ % effect on the data.

All impedance values are referenced to the output of the combiner boards. The 1-2 GHz combiner boards were measured to have a 0.4 dB loss and the 2-4 GHz combiner boards have a 0.2 dB loss. Moreover, there were losses due to an impedance mismatch between the 100 Ω combiner boards and the electrode assemblies whose characteristic impedances have been given above.[4] These losses were as follows:

	Σ Mode	Δ Mode
1-2 GHz	.01 dB	.14 dB
2-4 GHz	.00 dB	.04 dB

Thus, the theoretical values displayed in the graphs and tables have been reduced by the combiner board and impedance mismatch losses. All impedances have been averaged over an octive bandwidth (1-2 GHz or 2-4 GHz). This averaging represents a 0.4 db reduction from the peak coupling impedance at mid-band. The measured data have been corrected for the 1.56 dB (measured for the 2-4 GHz pickup) losses from the hybrids and cables, as well as all system and cable attenuations after the hybrid.

There is reasonably good agreement between the measured and calculated values. Data for the 2-4 GHz Δ mode used to be about 50% of the calculated values. However, after obtaining better system calibrations, the data come to within 20% of the calculated values.

Table 1

SUM MODE COUPLING IMPEDANCE IN OHMS, 1-2 GHZ, Y=0 MM

X (CM)	Z (POISSON)[†]	Z (DATA)	Z (FIT)[*]
-7	0.844	0.948	0.64
-6	2.39	2.17	1.86
-5	6.86	5.49	5.23
-4	19.19	15.36	14.8
-3	50.16	42.74	40.9
-2	102.22	91.07	95.3
-1	147.25	150.71	150.6
0	162.06	170.48	173.0
1	147.25	171.19	165.8
2	102.22	125.60	126.1
3	50.16	61.55	64.6
4	19.19	25.83	24.7
5	6.86	9.29	8.78
6	2.39	3.52	3.09
7	0.844	1.39	1.08

[†] Z_{pu} = 108.5 Ω calculated from Poisson data.

[*] TEV-I functional form fit with: w = 4.4 cm, h = 3 cm
  Z_{pu} = 109.0 Ω and Z(Max) = 175 Ω)
  (horizontal offset = 0.25 cm)

Table III

SUM MODE COUPLING IMPEDANCE IN OHMS, 2-4 GHZ, Y=0 MM

X (CM)	Z (POISSON)[†]	Z (DATA)	Z (FIT)[*]
-7	0.146	0.27	0.22
-6	0.610	0.81	0.62
-5	1.80	2.13	1.75
-4	5.10	5.35	4.99
-3	14.33	14.6	14.2
-2	38.47	39.8	38.8
-1	83.04	93.8	88.2
0	109.67	121.2	120.7
1	83.04	82.5	88.2
2	38.47	37.6	38.8
3	14.33	13.5	14.2
4	5.10	4.71	4.99
5	1.80	1.93	1.75
6	0.610	0.80	0.62
7	0.146	0.29	0.22

[†] Z_{pu} = 92.6 ohms calculated from Poisson Data.
[*] Fit of TeV-I functional form with w = 1.86 cm, h = 3.0 cm
     Beam Width = 7 mm and Z_{pu} = 139.4 ohms.

Table V

SUM MODE SENSITIVITY, 1-2 GHZ

X (CM)	S (X,0)
-8	0.00161
-7	0.00444
-6	0.0126
-5	0.0361
-4	0.101
-3	0.264
-2	0.538
-1.75	0.608
-1.50	0.673
-1.25	0.729
-1	0.775
-0.75	0.810
-0.50	0.834
-0.25	0.848
0	0.853
0.25	0.848
0.50	0.834
0.75	0.810
1	0.775
1.25	0.729
1.50	0.673
1.75	0.608
2	0.538
3	0.264
4	0.101
5	0.0361
6	0.0126
7	0.00444
8	0.00161

Table VII

SUM MODE SENSITIVITY, 2-4 GHZ

X (CM)	S(X,0)
-7	0.00788
-6	0.00330
-5	0.00971
-4	0.0276
-3	0.0775
-2	0.208
-1.75	0.261
-1.50	0.321
-1.25	0.385
-1	0.449
-0.75	0.508
-0.50	0.553
-0.25	0.583
0	0.593
0.25	0.583
0.50	0.553
0.75	0.508
1	0.449
1.25	0.385
1.50	0.321
1.75	0.261
2	0.208
3	0.0775
4	0.0276
5	0.00971
6	0.00330
7	0.000788

Table IX

SUMMARY OF PU RESPONSE

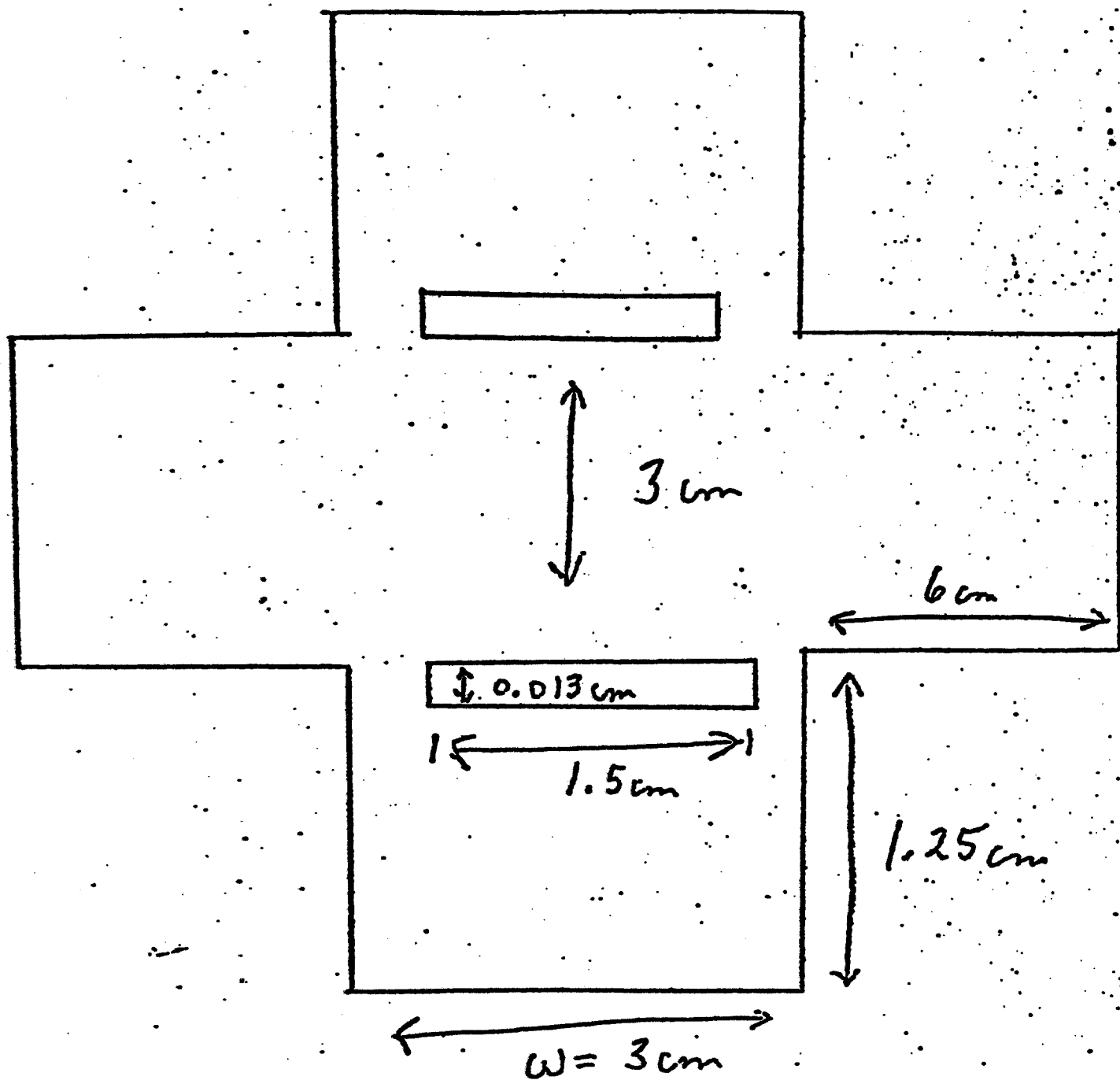| Pickup System	Para- meter	Design Calculation	Poisson Calculation	Measured	Loss
1-2 GHzΣ	Z (X = 0)	42Ω	40.5Ω	48.8Ω	-0.8db
1-2 GHzΔ	Z'(Y = 0)	32Ω/cm	24Ω/cm	23Ω/cm	+0.4db
2-4 GHzΣ	Z (X = 0)	29Ω	28Ω	30Ω	-0.6db
2-4 GHzΔ	Z'(Y = 0)	25Ω/cm	22Ω/cm	20Ω/cm	+1db

3 cm

6 cm

$\updownarrow$ 0.013 cm

1.5 cm

1.25 cm

W = 3 cm

FIGURE 2

2-4 GHz GEOMETRY

DIFFERENCE MODE SENSITIVITY. 1-2 GHZ

Y POSITION (MM)

D10.Y)
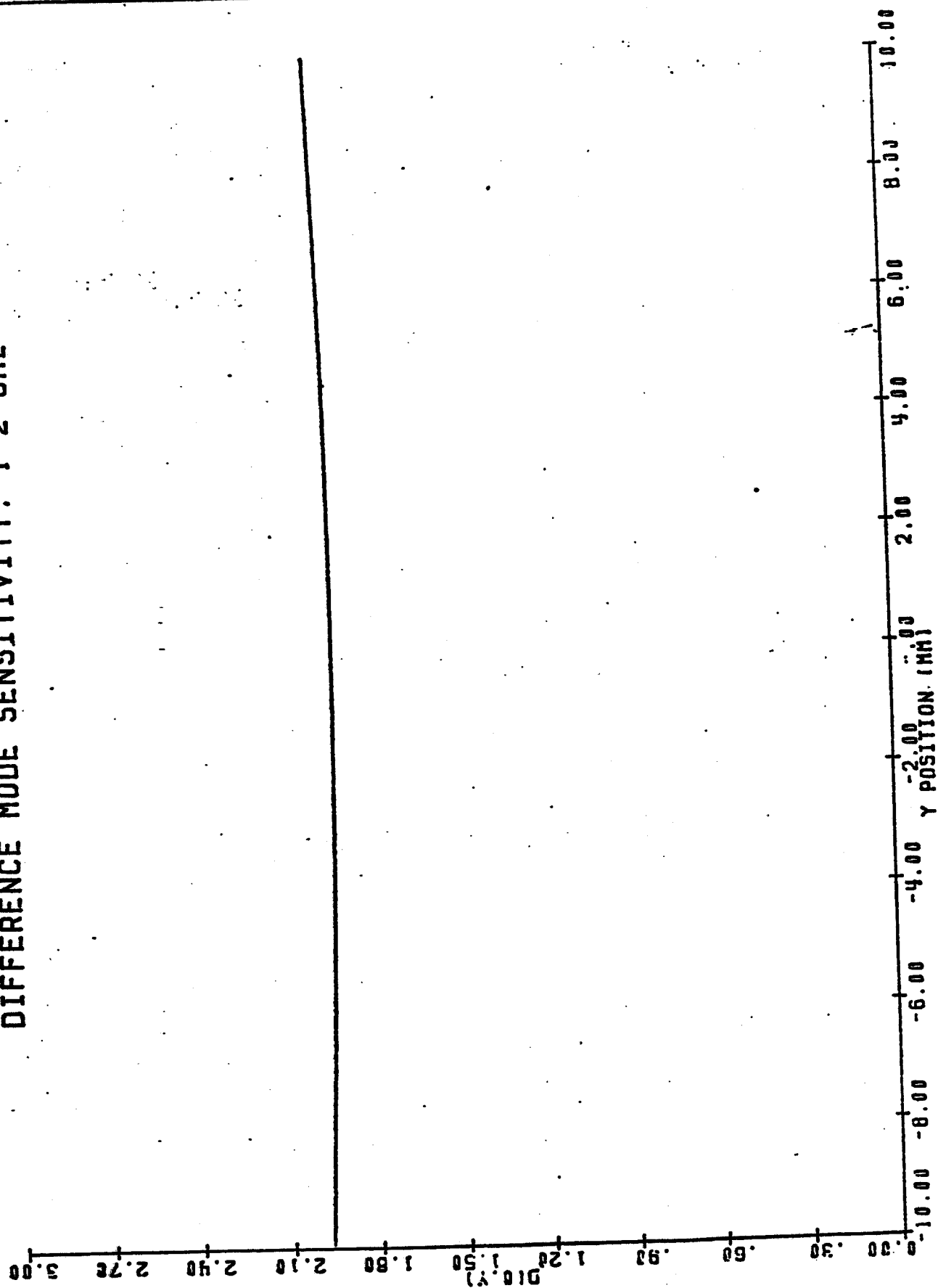
FIG. 4

DIFFERENCE MODE SENSITIVITY, 2-4 GHZ
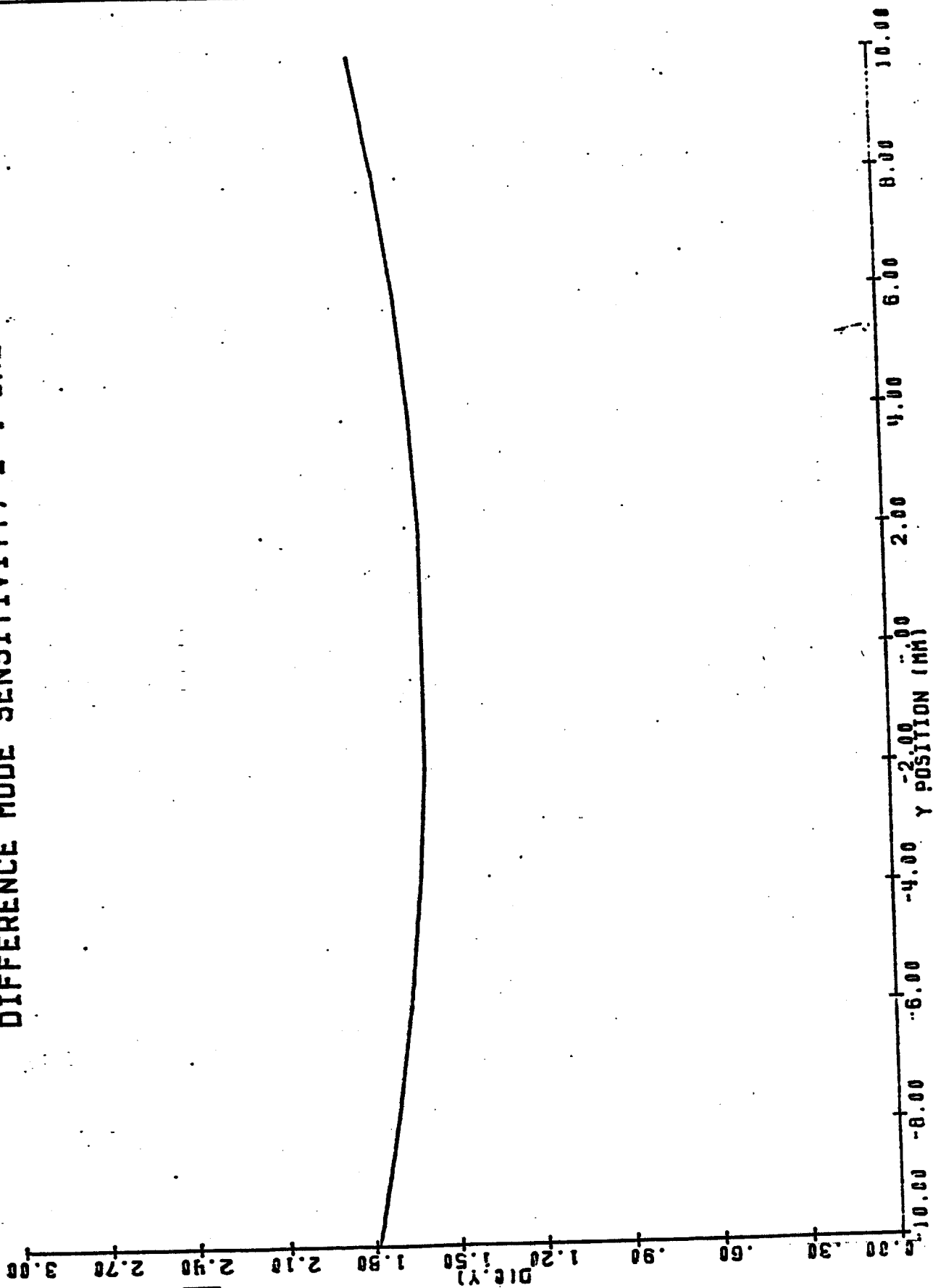
FIG. 6

1-2GHZ PICKUP SUM MODE COMB.

+ TS2000 SERIES

—POISSON CALC. Zpu=108.5

-- TaV-I w=4.4/h=3CM.
Zpu=109ohms BW=7mm.

(X(offset)=.25cm.)

Zc in ohms

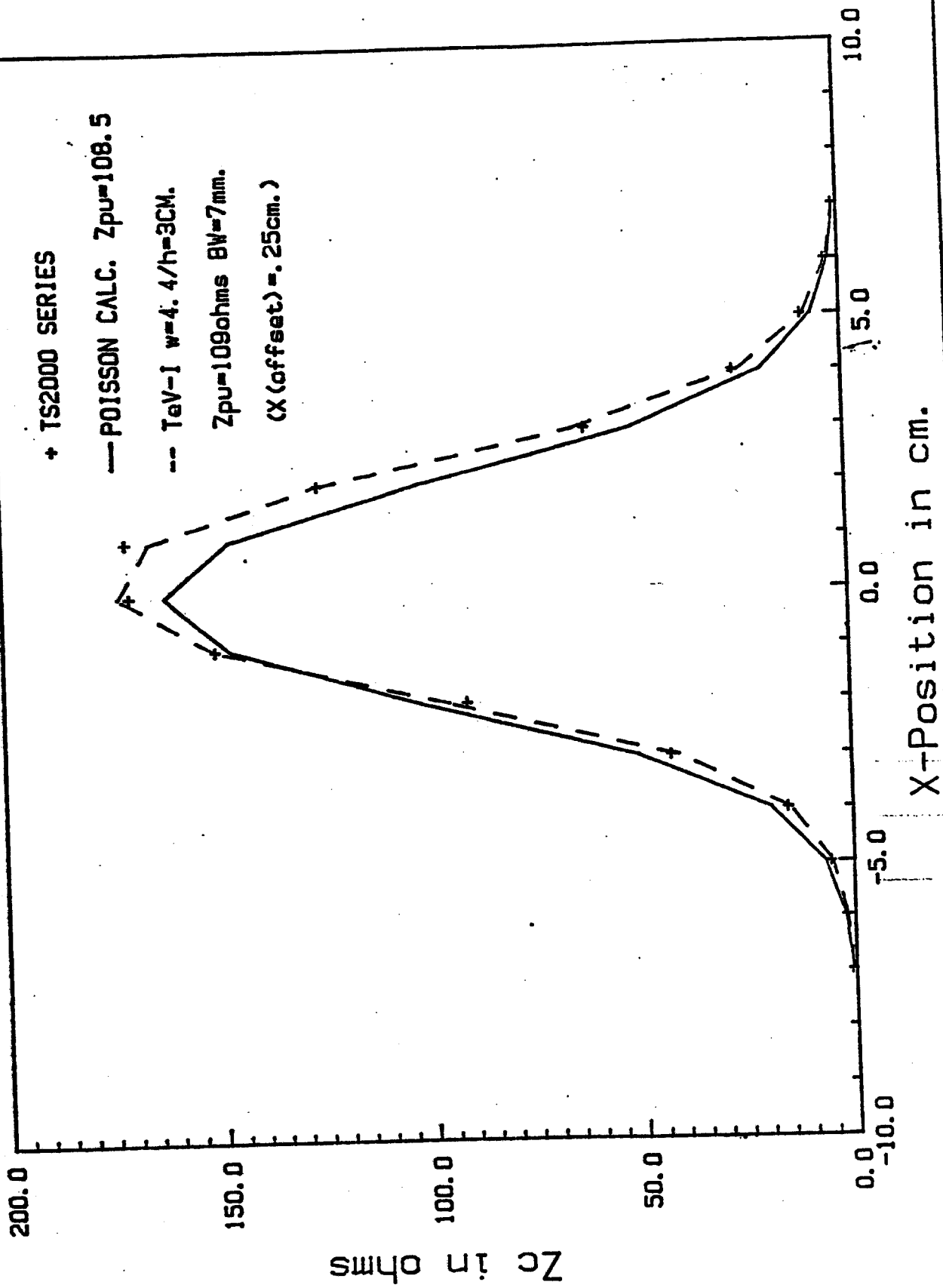200.0

150.0

100.0

50.0

0.0

-10.0   -5.0   0.0   5.0   10.0

X-Position in cm.

Fig. (8)   1-2 GHz Pickup Sum Mode output from Combiner Board

Fig.(10) 2-4 GHz Pickup Sum Mode (Output from Combiner Boar

2-4GHZ PICKUP DELTA MODE COMB.

+ TD4500 SERIES 5/25/84

—— POISSON CALC. Zpu=82.7 ohms

-- TEV-1 Zpu=82.7 ohms
   Z'=97.4 ohms/cm. (5mm.)

---- LIN. FIT Z'=79.2ohms/cm.

Y-Position in mm.

Zc in ohms
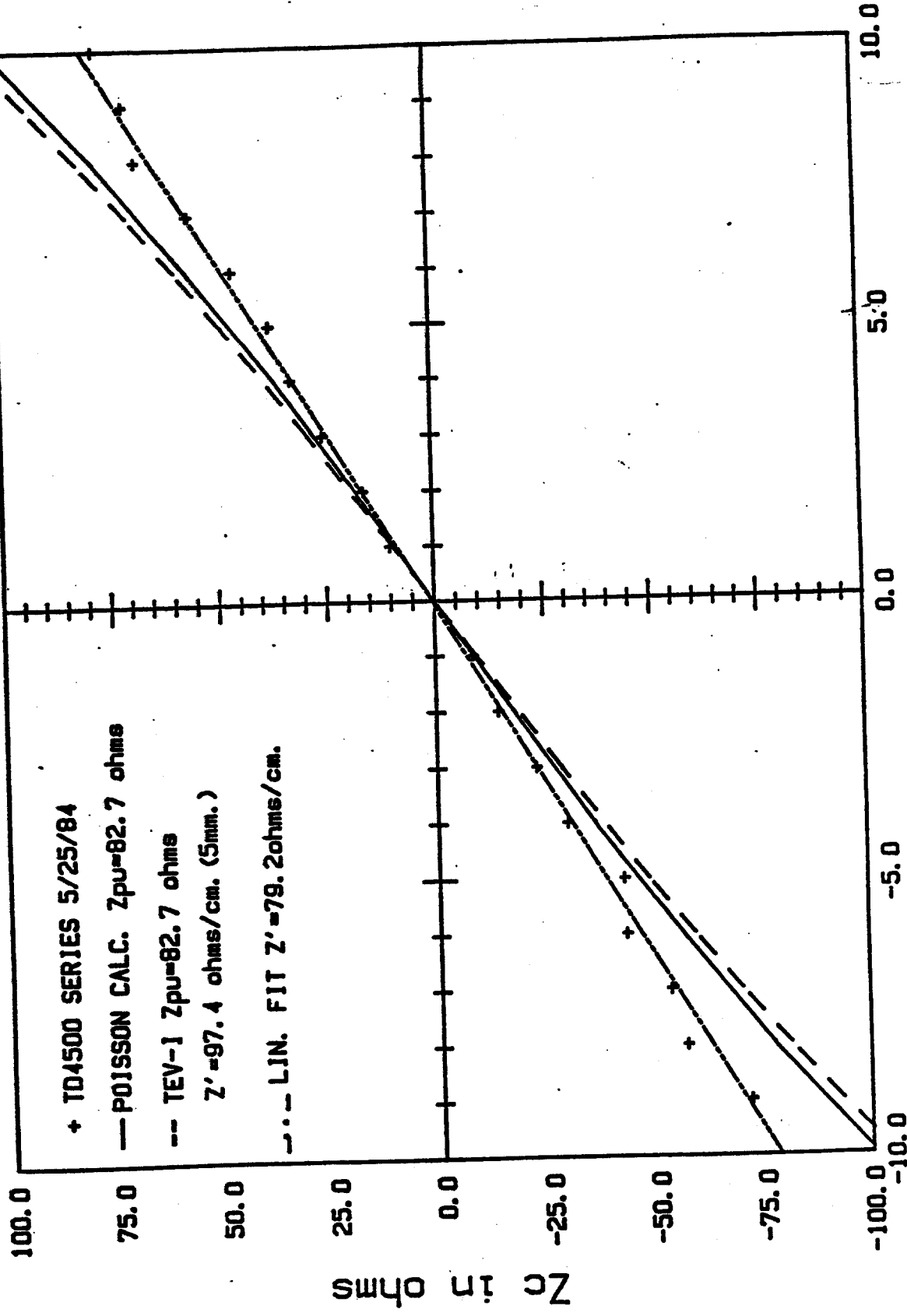
2-4GHz Difference Mode (output from Combiner Board)
Data offset by 1mm. from measurement

Fig (17)